BANCA D'ITALIA
EUROSISTEMA

Covid-19 Note
May 27, 2020

FIGHTING COVID-19: MEASURING THE RESTRICTIVENESS OF GOVERNMENT POLICIES

FRANCESCO PAOLO CONTEDUCA, MICHELE MANCINI, LUCA ROSSI AND FLAVIA TONELLI[1]

Governments have enacted restrictive measures to prevent, control, and contain the COVID-19 epidemic. In this note, we classify the containment measures adopted in Belgium, China, France, Germany, Italy, Japan, the Netherlands, South Korea, Spain, Sweden, the UK, and the US, which on the whole account for about 54% of worldwide reported infections and 74% of fatalities. We compute a synthetic score of restrictiveness based on the intensity and geographical scope of limitations to economic and social activities. The restrictions reduced citizens' mobility, especially in those countries that enforced a strict lockdown. The quantitative assessment of the causal effect of restrictive measures on the epidemic spread is beyond the scope of this note. However, the drop recorded in the new cases in Italy and other countries closely followed the increase in the stringency of the measures, something that hints at the fact that lockdown policies were successful in curbing the spread of infections, albeit with different timing and speed. Differences in lockdown easing depend mainly on the stage of the epidemic, the severity and the geographical scope of the measures adopted. Precautionary provisions and recommendations will still be in place to prevent new outbreaks. Insofar, in countries that have relaxed containment measures mobility is still far below normal times.

1. Government policies and population responses in the wake of COVID-19

The COVID-19 pandemic has harshly affected several countries in Asia, Europe, and North America albeit with a different timing, and has now reached other regions of the world, as Latin America. After spreading in China and the first cases being reported in other Asian countries (e.g. South Korea and Japan), the contagion moved to Europe and North America with the US rapidly becoming the most affected country in terms of reported cases and deaths. As of May 27, the number of worldwide reported cases is about 5.6 million with almost 350,000 deaths. In this note, we focus on Belgium, China, France, Germany, Italy, Japan, the Netherlands, South Korea, Spain, Sweden, the UK, and the US. These countries are particularly interesting to understand the dynamics of the contagion and its relation to policy measure for two reasons. First, they were severely affected by the epidemic, accounting for about 54% of worldwide reported infections and 74% of fatalities. Second, to achieve their goal of either suppression or delay and mitigation (i.e. attempting to control the spread of the

[1] Banca d'Italia, International Relations and Economics Directorate. The opinions expressed and conclusions drawn are those of the authors and do not necessarily reflect the views of the Bank of Italy.

infections without exceeding the capacity of the healthcare systems while at the same time expanding it), these countries adopted different strategies, ranging from massive testing to different degrees of regional and nationwide lockdown.

Based on the heterogeneity in the severity in the policy restrictiveness, we propose the following classification:[2]

1. Full lockdown: strict restrictions on citizens' activities and movements (e.g., stay-at-home orders, closure of non-essential businesses[3] and other production activities, ban on all public gatherings and public events, restrictions to the freedom of movement). Examples are Italy, Spain, France, the UK, the Hubei region in China, and some states of the US, like New York and California.
2. Mild lockdown: restrictions less severe than a full lockdown, often coming in terms of recommendations and relying on public trust. Examples are the Netherlands, Germany, and some US rural states like Nebraska, North Dakota, and South Dakota.
3. No lockdown - alternative measures: exclusion of widespread lockdowns and adoption of other tools, which may differ by country. For example, South Korea resorted to massive testing and extensive tracing in the early stages of the outbreak to isolate and treat patients to avoid local community transmission. Japan relied on a cluster-based approach pinpointing limited testing to identify and isolate super-spreaders. Sweden followed a low-intensity mitigation strategy, relying more on public trust and the establishment of social norms rather than law enforcement.

The policies were highly heterogeneous not only across countries but also markedly differed within them: depending on the domestic evolution of the epidemic and the legal system (i.e., federal vs central states), the entry into force of responses occurred with different timing and intensity across different areas of the same country. Italy was no exception: as the outset of the outbreak emerged in few municipalities in Lombardia and Veneto, the initial quarantine, despite being strict, involved a small fraction of the whole population (50,000 inhabitants). Following the intensification of the epidemic, the containment measure was extended to the whole of Lombardia and 14 provinces of the other northern regions (about 16.7 million inhabitants). Two days later, the quarantine became nationwide. Other countries (e.g. Germany, the US, and Spain) followed a similar path, implementing progressively the lockdown at the subnational level. Consequently, to evaluate properly their level of restrictiveness, the actual share of population involved has to be taken into account.

To assess quantitatively the stringency of the measures in relative terms, we compute a Lockdown Index that accounts for both the intensity of the measures and the regional pattern of the enforcement, relying on information sourced from official statements and media outlets,[4] and it summarizes three dimensions: *i*) school closures, *ii*) economic activity shutdown, *iii*) stay-at-home requirements. The intensity of each policy is weighed by the fraction of the population targeted. Table A1 in the Appendix presents the variables entering the computation of the index in details.

[2] Most countries opted for a mix of restrictions, testing, and health recommendations to the public. In our taxonomy, we mainly looked at the implementation of a lockdown. If a lockdown was not adopted, we considered the most distinctive features of the alternative strategy followed.

[3] The definition of non-essential business differs across countries. However, essential business includes supermarkets and grocery stores, pharmacies, garbage collection, healthcare, and gas stations.

[4] We acknowledge that the reliability of collected information from media outlets is limited, especially that regarding measures adopted in Chinese provinces.

To compute the lockdown index, we expand the methodology developed by the Oxford COVID-19 Government Response Tracker (Oxford index, see Hale et al. 2020 for a detailed description). With respect to the index produced by Hale et al. (2020), we make three contributions. First, we redefine the score of the variables and the objective of their measure. For instance, within the economic activity sub-index, our score is maximum only if a country halted non-essential productions, as in the case of Italy and Spain. The Oxford Index instead assigns the maximum score to restrictions on economic activity implemented in the Netherlands, South Korea, Italy, and Spain, not taking into account that the restrictions in the Netherlands and South Korea were milder than in the other two countries.[5] Second, we weigh measures applied at the subnational level by the share of targeted population. Third, to avoid double counting, we use a restricted set of variables as compared to those featured in the Oxford index.[6] The Appendix details the construction of our Index.

Table 1 shows for each country the date of maximum restrictiveness, together with the value attained by the Lockdown Index, and its sub-indices, i.e. *school closures*, *economic activity shutdown*, *and stay-at-home requirements*. It also reports the ratio between the number of tests and cases as a proxy for the intensity of testing efforts ongoing in each country.

Table 1. Lockdown index: lockdown date, maximum value, sub-indices and testing policies.

	Date of Lockdown	Maximum Lockdown Index	Sub-indices: *School*	*Economic activity*	*Stay-at-home*	Tests/cases*
Italy	10-mar-20	100	100	100	100	12
Spain	14-mar-20	100	100	100	100	7
France	17-mar-20	89	100	67	100	6
United Kingdom	23-mar-20	89	100	67	100	7
United States	19-mar-20	85	99	63	94	7
Belgium	18-mar-20	78	67	67	100	9
China	23-gen-20	72	100	100	17	n.a.
Germany	23-mar-20	70	100	67	43	17
Netherlands	16-mar-20	61	100	33	50	6
South Korea	24-feb-20	61	100	33	50	62
Japan	07-apr-20	50	67	33	50	14
Sweden	16-mar-20	22	33	33	0	7

* Source: authors calculations on data from https://ourworldindata.org/coronavirus-testing.
Note: tests/cases is the ratio of number of tests to number of cases.

The above qualitative classification is consistent with the quantitative assessment provided by the Lockdown Index. In particular, the index attained the highest values in Italy, Spain, France, and the UK. The difference between France and the UK, and Italy and Spain hinged on the fact that the last two countries enforced also more stringent measures on the economic activity side than the first two, i.e. they halted non-essential production. Other countries like Belgium, Germany, and, in particular,

[5] See the official statements of the governments in the Netherlands, South Korea, Italy, and Spain.
[6] For instance, the OxCGRT index gives equal weight to the requirement of stay-at-home and on restrictions on gatherings. However, once the former is enforced, the latter is directly attained. If the two policies are measured by different sub-indices, the total restrictiveness index is artificially overstated.

the Netherlands adopted milder measures. South Korea resorted to massive testing and extensive tracing in the early stages of the outbreak to isolate and treat patients to avoid local community transmission (last column of Table 1). In addition, it opted for closing schools and recommended smart working to slow down the contagion. Japan and Sweden did not enforce a lockdown so they attained lower values of the index. The index takes into account also the geographical scope of the measures. Indeed, its values in the US and China reflect the heterogeneity at the state and province levels. In particular, in China the harshest measures, possibly more stringent than that in the other countries, were in force only in the province of Hubei that accounts for about 4% of the Chinese population. Besides the level of stringency of the adopted policies, another dimension to consider is the length of the period in which they were in force. Indeed, all countries kept their measures in place for several weeks.

The containment measures deeply affected citizens' daily life. *De iure* restrictions, especially those aimed at increasing social distancing, result in changes of people's behavior. Mobility trends' data – as measured by the Google COVID-19 Community Mobility Report[7] – reflect both the effects of the restrictions and community compliance. In most countries, as soon as the restrictions entered into force, mobility – associated with retail and recreational activities and commuting – dropped dramatically (Figure 1). In particular, retail and recreational mobility dropped by at least 80% with respect to normal times in countries that followed a strict lockdown strategy (Spain, Italy, France, and the UK). Conversely, mobility declined by less than 40% in those countries where a lockdown was not imposed (Japan, Sweden, and South Korea).[8] Between these two extremes, three countries stand out: the US, where the "stay-at-home" policy was not mandatory in every state (ordered in Washington D.C. and 43 out of 50 states); the Netherlands, which followed a mild lockdown; Germany, which never enforced a strict nationwide "stay-at-home" policy (with some heterogeneity across federal states). We found similar patterns, albeit less pronounced, in terms of workplace mobility.

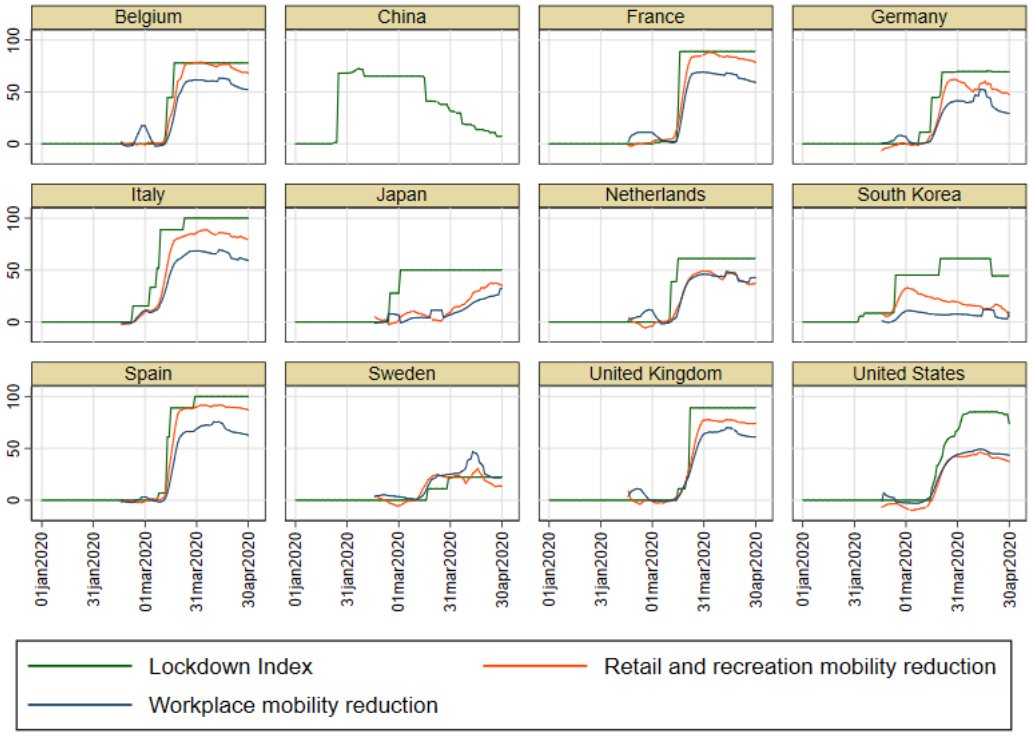
We can test the ability of our index to capture the restrictions intensity by estimating the share of variance of the change in mobility that is explained by the lockdown index itself.[9] To this end, we run a regression of the mobility indicator on the lockdown index. Our index explains about 80% of the total variance of the mobility changes, around 10 percentage points more than the Oxford index.

[7] The index computed by Google measures the change in mobility with respect to the median value observed during the five-week period January 3 – February 6.

[8] Other sources of data on mobility, like the Mobility Trend Reports issued by Apple, show that the reduction in mobility in South Korea has been more marked than what Google reports. However, because the latter source provides more detailed information, it is used as the benchmark for mobility throughout the note.

[9] A caveat is in order. The Lockdown Index is not meant to capture the effectiveness of the measure. However, we expect that tougher restrictions should result in larger reductions of mobility.

Figure 1. Lockdown Index and mobility reduction.



Source: Google Covid-19 Community Mobility Reports. Mobility data are not available for China.

Evidence suggests that restrictive measures contributed decisively to curbing the epidemics. Before restrictive measures were imposed, the number of people infected was rapidly increasing (see Figure 2) while about 15-20 days after the introduction of the measures the number of new cases peaked and then started to decline, consistently with the sum of the average incubation period and the typical delay in testing and recording of the results.

In particular, we observe that the number of new cases in countries adopting stricter containment policies (Italy, Spain, and France), as measured by the Lockdown Index, generally decreased faster from the epidemic peak than in other countries, with the exception of the UK. However, the UK massively increased its testing capacity starting from the beginning of April. Hence, the slower drop in new cases may reflect also the detection of a large share of previously undetected individuals.[10] New cases flatten in a similar way, albeit less rapidly, in Belgium and the Netherlands. Figure 1 also suggests that testing is crucial to dampen the epidemic. South Korea and Japan were able to curb the contagion by combining recommendations and relatively mild measures on social distancing with ad hoc testing strategies. Germany also succeeded in controlling the spread of the epidemic by following a similar strategy (i.e. by implementing large-scale testing in combination with a relatively mild lockdown). The number of new cases in Sweden peaked after a longer period, compared to other countries, possibly because of its loose strategy, as shown by the Lockdown Index. Despite some estimates showing that Sweden was able to move towards epidemic containment in April,[11] its

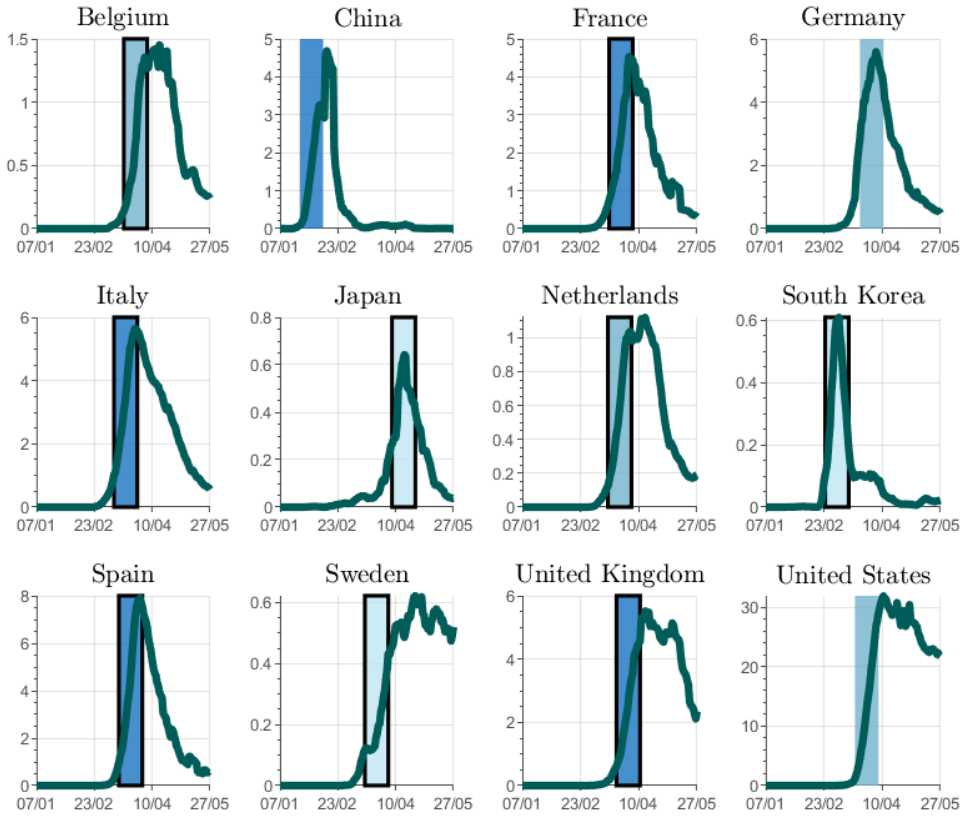
[10] Testing capacity in the UK lagged with respect to several European countries of similar size. In particular, the number of daily tests in the UK reached a plateau of around 60 thousands tests per day only at the beginning of May while a similar testing rate was registered since mid-April in Italy and Spain.

[11] See the report issued by the Swedish Public Health Agency.

mortality rate was considerably higher than that of other Nordic countries that, instead, enforced a mild lockdown, i.e. Denmark, Norway, and Finland (see Figure 3a and 3b).

The US represents a specific case. First, the epidemic spread with different intensity and timing across the states. New York, New Jersey, Massachusetts, and Rhode Island reported a large number of cases (the ratio of reported cases to population exceeds 1%, between 3 - 5 times that of Italy, and 1.5 - 2 times that of Lombardia, the hardest-hit Italian region). On the opposite, Montana, Hawaii, Alaska, West Virginia, and Oregon reported less than one case per thousand inhabitants. In addition, the number of reported new cases is heterogeneous across states: in the second week of May, new cases were still on an increasing path in some states such as Texas, Minnesota, Arizona, Kentucky, and Virginia among others, while they were decreasing in New York, New Jersey, Massachusetts, and Pennsylvania. Even the timing of the lockdown measures was different across the states, ranging between March 19 and April 7 (see Figure 4). Moreover, several states adopted short-lived lockdown periods that did not match the trend of the epidemic: for example, the stay-at-home order in Texas, issued on April 2, expired on April 30, despite the epidemic curve being still on an increasing path. All these factors may explain why the US reduction of the number of new cases has been relatively slower than in other countries.

Figure 2. Number of new cases and lockdown across countries (7-day moving average of daily new cases, in thousand)



Note: The shaded areas start from dates when restrictive measures have been in place. Dark-blue, medium-blue, and light-blue areas are used for countries that adopted strict, mild, or alternative measures respectively. Black edges around the areas denote countries that enacted nationwide (as opposed to regional) measures. For the USA, the shaded area starts the day at which California announced the lockdown, becoming the first US state adopting such measure. All the shaded areas end after 20 days. Data from the European Centre for Disease Prevention and Control.

Figure 3a. Case fatality rate in Nordic countries

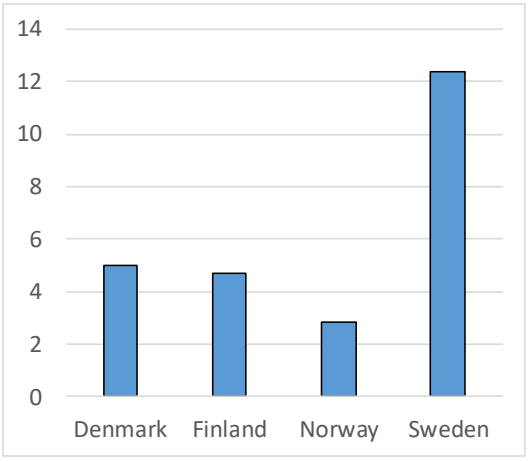


Figure 3b. Covid-19 deaths per million inhabitants in Nordic countries

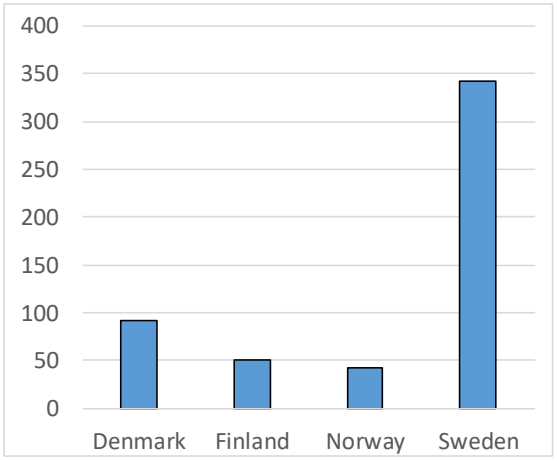
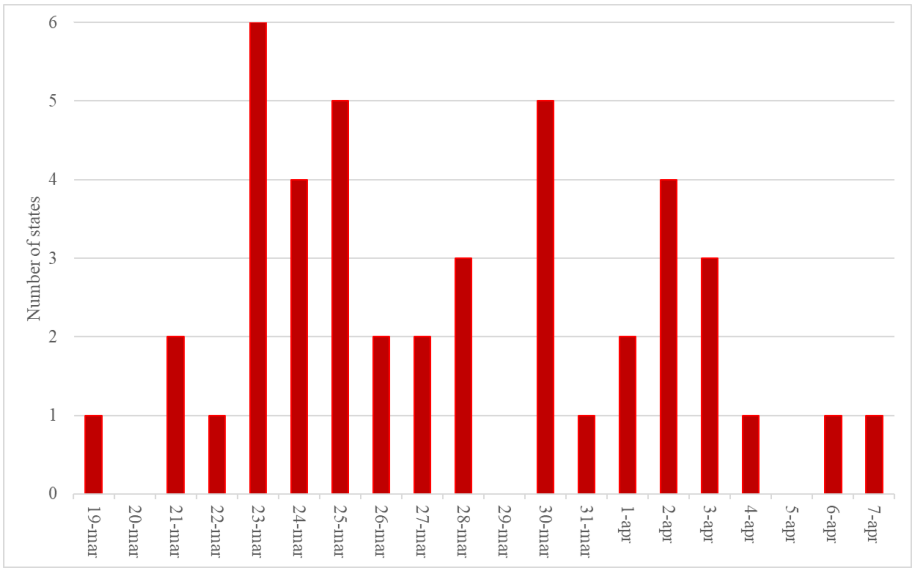


Figure 4. Time distribution of stay-at-home orders across US states.



Source: U.S. state and local government response to the COVID-19 pandemic, Stateside.

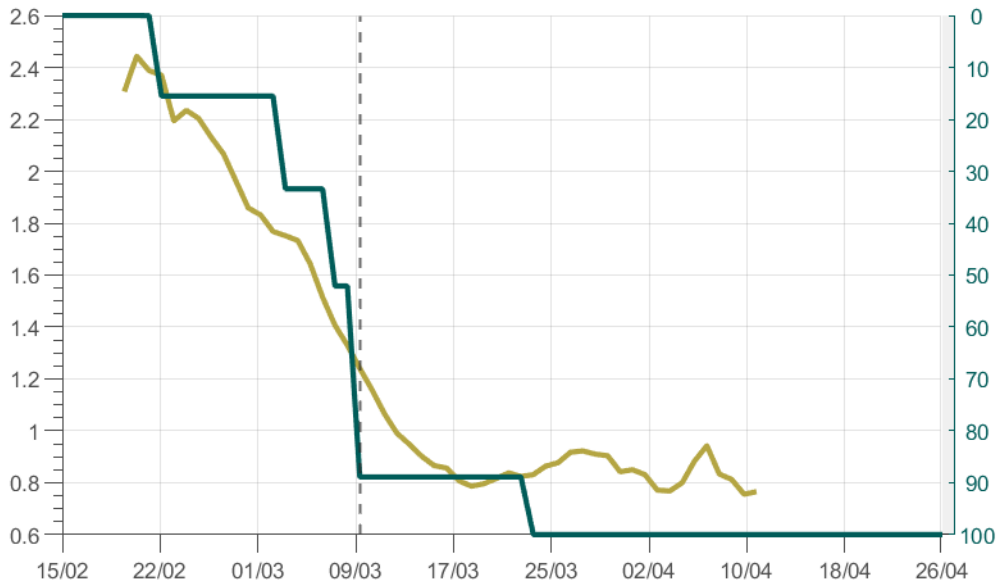
Overall, this *descriptive* evidence suggests that all countries managed to flatten the epidemic curve, i.e. reducing the speed of contagion (the reproduction number, R_t), although with different strategies. In some, the goal was achieved with a sizable reduction in mobility, driven by very strict lockdowns; in others, with testing and tracing policies and targeted closures of clusters and/or regions. Finally, when countries resorted to stricter containment policies, as measured by the Lockdown Index, the epidemic peaked faster than elsewhere. In addition, reduced mobility occurred also in countries that did not enforce stay-at-home orders, pointing to behavioral changes (e.g. Sweden).

Recently, some authors have tried to estimate the *causal* effect of policies on the reproduction number (see Vollmer et al., 2020), modelling R_t as a function of mobility indicators. Yet, a clean identification

strategy is seriously complicated by the fact that both mobility and reproduction number are simultaneously determined by a mix of legal restrictions, policy measures, changing individual behaviors and expectations on the future evolution of contagion.

While cause-and-effect analysis is beyond the scope of this note, we provide a qualitative assessment on the co-movements between policy restrictiveness and R_t in the case of Italy. Our estimates computed from a SIR model for the reproduction number, R_t, suggest that, starting from a value of 2.2 on the day of the national lockdown (March 10), it fell to 1 by the end of March, and fluctuated around 0.8 afterwards, entailing the subsequent reduction in both the number of new cases and of deaths.[12] If we lag the reproduction number by 15 days to account for delays in symptoms onset and in detection and registration of new infections in the national statistics, the speed of infection moves hand-in-hand with the severity of restrictions enforced by the Italian government (Figure 5).

Figure 5. Lockdown Index and estimates of the effective reproduction number in Italy.



Note: This figure plots data for the inverse Lockdown Index (green line, inverted right axis), and our estimate of the effective reproduction number (yellow line, left axis). The dashed vertical line is on March 10, the day of the nationwide lockdown. For the reproduction number, we report estimates starting from March 6, which are drawn in the figure from February 20 because of the assumed lag of 15 days in the case reporting.

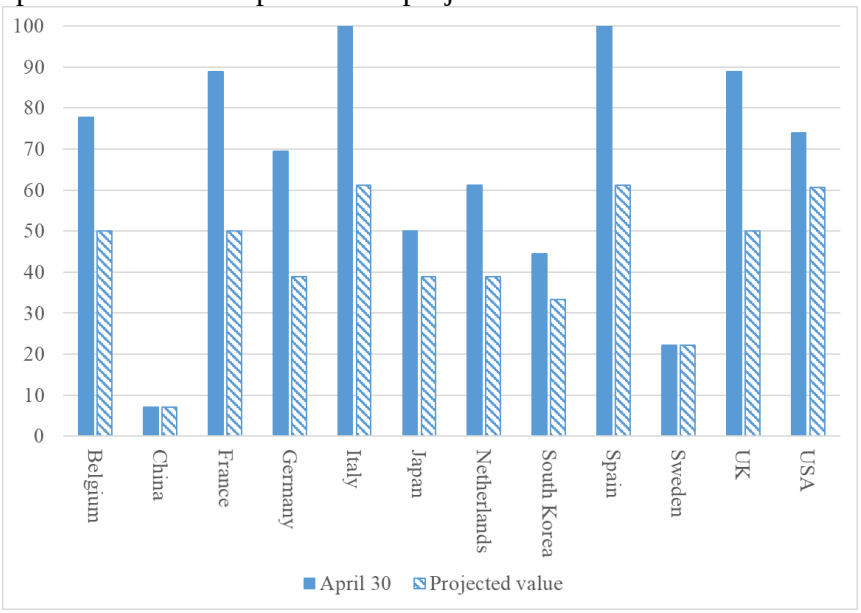
2. Restarting after COVID-19: qualitative assessment on re-openings

The easing of the lockdown and the gradual restart of economic activities and social interactions is proceeding similarly across countries, following the improvement of the epidemiological situation. Still, some differences stand out, depending on the severity of the measures adopted and on the stage of the epidemic.

[12] We estimate R_t using the equations from a SIR model. We cast the model in a state-space representation by assuming R_t to evolve as a random walk, and estimate the system with the particle filter as in Liu and West (2001). These estimates are broadly in line with the most recent assessment by the Istituto Superiore di Sanità (ISS) and the Bruno Kessler Foundation. See Guzzetta et al. (2020).

Figure 6 shows the projections of the Lockdown Index based on the measures to restart the economic and public activities. In particular, we compare the value of the index as computed on April 30 with its expected value conditional on the announced easing measures scheduled until June. The Lockdown Index is projected to drop in most countries by an amount that depends on three factors: first, the current degree of restrictiveness; second, regional/national scope of the current and announced policies; third, the prospects concerning school openings. In particular, we expect a larger value of the index (more restrictive) for the US, Italy, and Spain where the governments deferred school openings until September. Other countries restarted or announced a gradual opening of schools, though they maintained some limitations on their activities. Moreover, most countries will not entirely lift up restrictions and recommendations on business activities (e.g. remote working, limited access to factories and offices), physical distancing, and staying-at-home. Indeed, despite the re-openings, as of mid-May mobility was still far below the baseline level recorded in January (Figure 7a and 7b).

Figure 6. Comparison between April 30 and projected values of the Lockdown Index (June).



Source: authors' computation based on official statements and media reports.

Figure 7a. Retail and recreation mobility.

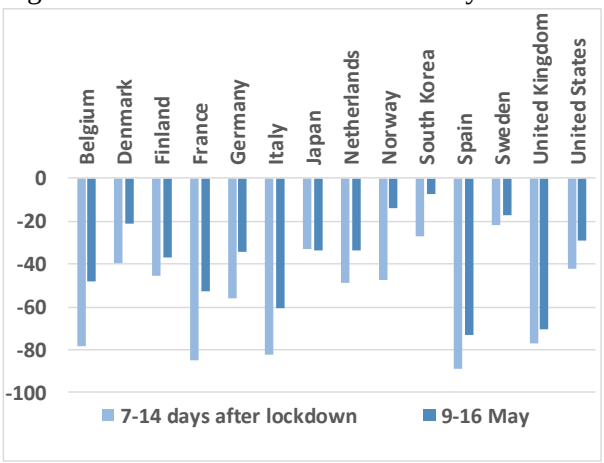
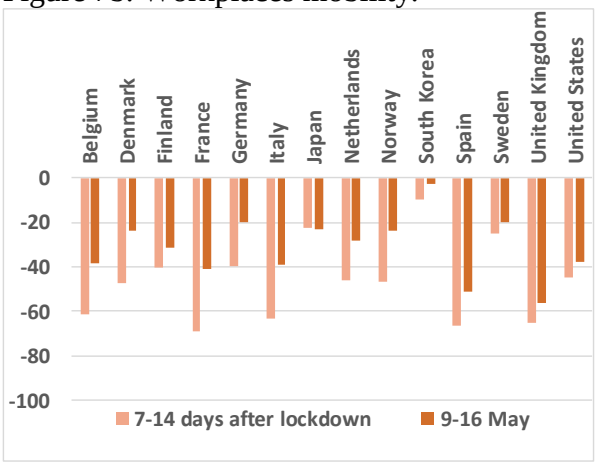


Figure 7b. Workplaces mobility.



Source: Google Covid-19 Community Mobility Reports.

Table 2 presents more in detail the different restarting measures with a particular focus on schooling and business activities.

While the scientific literature has not yet reached a consensus about the spread of COVID-19 contagion among youngsters and their role in the transmission of the infection among the rest of the population,[13] most countries set up plans to allow students to resume their school activities. During the most severe stages of the epidemic, education institutions tried to substitute traditional classrooms with distance learning. As the epidemic slowed down, governments looked for policies that allow a safe return to on-site classes. Since April, Chinese students have their temperatures checked at school entrances needing a "green light" issued by a government mobile app. In Japan, local municipalities, reporting low infection rates, started to re-open their schools – 40% of Japanese schools re-opened as of May 2 – after they improved ventilation, implemented safe distancing and mask wearing. Other countries such as Germany, France, the Netherlands, Belgium, and South Korea, will gradually re-open schools between May and June, with some downsizing of classes, reduction in school hours and strengthening of "distance learning". Other countries, like Italy and Spain, deferred school opening until September. Most schools remained open in Sweden.

Manufacturing, construction, and retail are usually the first sectors to be allowed to reopen. Since April, in the attempt of avoiding new outbreaks, Chinese companies adopted strict checks. Strategies included daily temperature checks and mandatory facemasks wearing. In the manufacturing sector, some workers were not allowed to leave production plants without permission to prevent community transmission. Some companies adopted workers' segregation to preserve production in case of an outbreak. South Korea announced a further lifting-up of restrictive measures on businesses starting from May. Between April and May, Germany phased in a progressive easing based on the shop-floor area. In May, most American states started to reopen with restrictions, limiting the number of customers, mandatory masks, sanitization, and social distancing. In Spain, around 300,000 essential workers, unable to carry out remotely their activity, went back to their workplace on April 13. Other businesses reopened on a regional basis from May 11, the starting day of a de-escalation phase.

Despite the different policies, social distancing is required everywhere. Wearing mask is compulsory on public transport and indoor spaces in many countries. In China, citizens need to obtain the government approval via a mobile app to carry out daily activities, while in South Korea people downloaded the app on a voluntary basis. European countries and the state of New York are currently evaluating different voluntary-based mechanisms for contact tracing; some countries have already selected the app (for example, Italy). Some regions in Spain (Madrid and Catalonia) launched their own apps, with different features concerning the sharing of localization data. In the UK, an app has been under testing in the Isle of Wight; at the same time, the National Health System is developing an alternative one based on standards set by Apple and Google.

[13] See Fontanet et al. (2020) or Jones et al. (2020).

Table 2. Actual and announced reopening plans.

	SCHOOL	BUSINESS
BELGIUM	Maximum 10 students each class, for a couple of days a week (May 18).	Gradual reopening. May 4: fabric factories for masks and companies back to work. May 11: all shops under strict social distancing and hygienic rules. Only one customer per 10m², and for 30 minutes. Wearing mask recommended. June: restaurants and cafes. Wearing mask compulsory at the workplace.
CHINA	Gradually from April. Differences between provinces. Checking temperature and green health code needed.	Gradual reopening and on a regional basis. On February 22, provinces' staff returned to work; coal production and grain production and processing capacity gradually resumed. March 2: 300 million people back to work. March 11: Hubei province gradually reopened. Key industries in Wuhan also resumed, including public transport, medical supply, and production of daily necessities. Industries crucial to national or global supply chains required permission before resuming production. March 22: other activities in Wuhan resumed.
FRANCE	Gradually, from May 11. Wearing mask for children > 11 needed. No more than 10/15 students allowed in each class.	May 11: all shops, apart those in shopping malls. June: restaurants and cafes in low infection rate regions.
GERMANY	Gradually, from May 4. The details of how schools will reopen are up to Germany's 16 states to decide.	Stores with a shop floor of up to 800m^2 (April 27). May: all shops, but wearing masks and social distance will be needed. Restaurants will open gradually, between May and June, on a regional basis.
ITALY	Closed until September.	Gradual reopening of all activities. April 27: selected construction sites and wholesale trade for building and export. May 4: manufacturing, textile, fashion, automotive, glass sector, construction, wholesale, private construction sites, bars and takeaway restaurants. May 18: retail trade, restaurants and bars, hairdressers, beauty centers.
JAPAN	Gradually, from March 24. Regional decisions. Classroom ventilation, physical distancing, checking temperature and wearing masks needed.	Gradually reopen on a regional basis. May: Businesses activities including chain stores, bookshops, cafes, bars and sports clubs.

NETHERLANDS	Gradually, from May 11. Students will attend school half of the time. No social distancing for children < 12.	All shops open, but social distancing >1.5m needed. Up to 10 people can be served in outdoors spaces of bars. Take away from restaurants until June 1. May 11: close-contact professions reopening for business.
SOUTH KOREA	Gradually, from May 13.	During the epidemic, shops, restaurants and and many leisure facilities remained open. Work from home recommended. May 6: workers back to offices.
SPAIN	Closed until September.	Gradual reopening also on regional basis. April 13: manufacturing and construction (about 300,000 workers). May 4: hairdressers and other activities by appointment; take-away restaurants. May 5: small businesses and hotels; religious services and restaurants (at 30% of capacity).
SWEDEN	Primary school remained open.	No wholesale lockdown. Restaurants, bars, hairdressers, yoga studios, gyms and some cinemas even remained open. Recommended social distancing.
UK	Gradually restart from June.	April: manufacturers and building firms back to business. June: shops. July: hospitality industry. Further plans to be announced.
US	Only Montana allowed schools to reopen this academic year (May).	Gradual reopening on a state basis. Restrictions and social distancing on a state basis, too. May: economic activities reopening in an increasing number of states (retail, food and drink, personal care). New York state still locked down; manufacturing, retail and construction activities set to reopen in May 15.

References and data sources

Fontanet, A. et al., "Cluster of COVID-19 in northern France: A retrosepctive closed cohort study". *medRxiv*, April 23, 2020.

Guzzetta, G., et al. "The impact of a nation-wide lockdown on COVID-19 transmissibility in Italy." arXiv, no. 2004.12338, 2020.

Hale, T., Angrist, N., Kira, B., Petherick, A., Phillips, T., Webster, S., "Variation in Government Responses to COVID-19" *Version 5.0. Blavatnik School of Government Working Paper*, April 29, 2020.

Jones, T. C. et al., "An analysis of SARS-CoV-2 viral load by patient age". *Charité Research Network of Zoonotic Infectious Diseases*, April, 2020.

Liu, J. and M. West, "Combined state and parameter estimation in simulation-based filtering". In *Sequential Monte Carlo Methods in Practice*, 197-223. New York: Springer, 2001.

Vollmer, M., Mishra, S., Unwin, H., Gandy, A. et al, "Using mobility to estimate the transmission intensity of COVID-19 in Italy: a subnational analysis with future scenarios". *Imperial College London Working Paper*, May 4, 2020.

Appendix: calculation of the Lockdown Index

In this section, we discuss the construction of the Lockdown Index. The index aims to measure how the government measures restrict schooling, economic activity, and freedom of movement across countries in the attempt of curbing the spread of the epidemic.

The methodology to compute the lockdown index follows the one developed by the Oxford COVID-19 Government Response Tracker (*Oxford Index*, see Hale et al. 2020 for a detailed description). With respect to the index produced by Hale et al. (2020), we make three contributions. First, we redefine the score of the variables and what they measure. Second, we weigh the local measures by the share of population targeted by each policy whereas the *Oxford* index disregards this aspect. Third, we use a restricted set of variables with the respect to the *Oxford* index to avoid double counting. For instance, the *Oxford* index gives equal weight to the requirement of stay-at-home and to the restrictions on gatherings. However, once the former is enforced, the latter follows. If the two policies are represented by different sub-indices, the total restrictiveness index may be partly affected by double counting.

The Lockdown Index relies on the construction of sub-indices, each obtained from a policy variable v_i included in Table A1 with $i = 1, 2, 3$. Policy v_i can assume different levels of restrictiveness denoted by j. Let J denote the set of levels of restrictiveness that the policy v_i can take, with $\bar{v}_i$ corresponding to the maximum level of stringency. Then, in each country, the sub-index I_i is given by the following expression

$$I_i = 100 \cdot \sum_{j \in J} s_{i,j} \cdot \frac{\tilde{v}_{i,j}}{\bar{v}_i},$$

where $\tilde{v}_{i,j}$ represents the j-th intensity of the variable i and $s_{i,j}$ represents the share of population in the country affected by the restrictions of intensity $\tilde{v}_{i,j}$. The Lockdown Index is

$$I = \frac{1}{3}\sum_{i=1}^{3} I_i. \qquad (1)$$

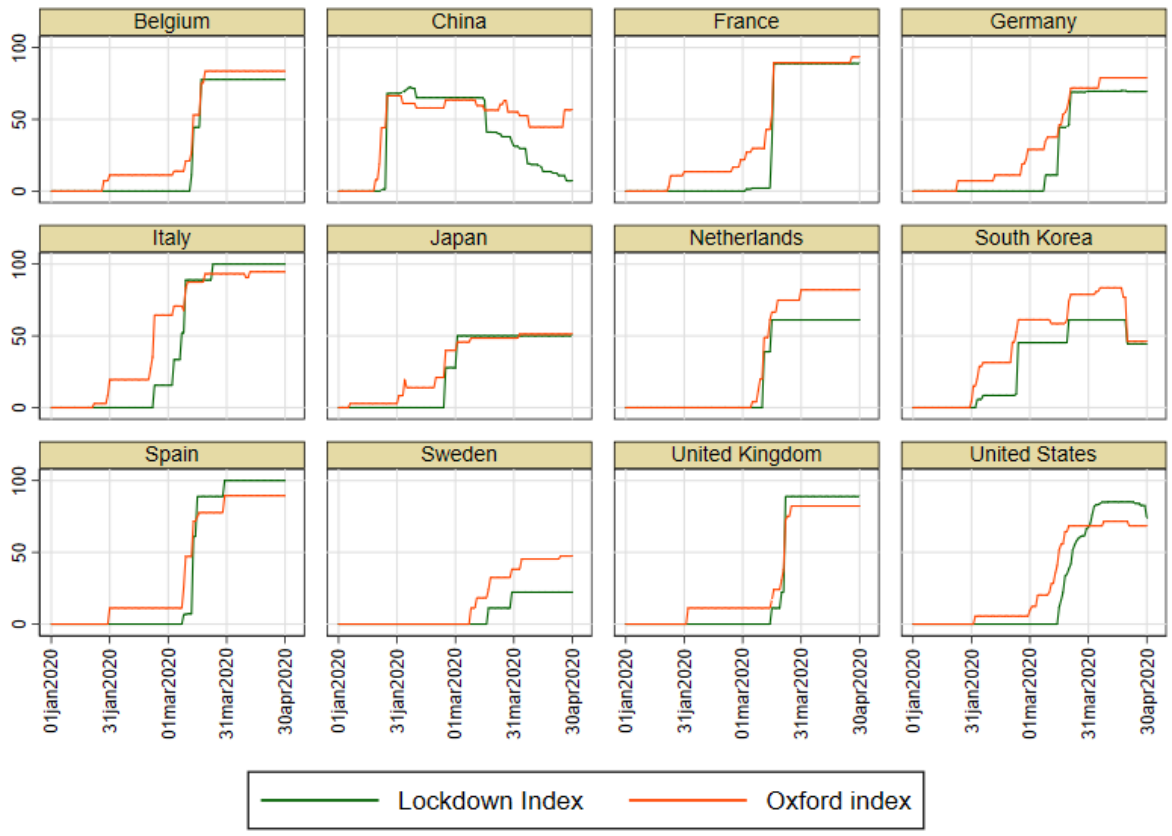
The index ranges between 0 and 100 with 100 corresponding to the case in which a country adopts the most stringent measures nationwide. Following the structure of the Oxford Index, we remain agnostic on the relative importance of each sub-index. Alternative possible specifications of the weighting may rely on further detailing the population share affected by the measures. For example, one could measure the stringency of school closure by considering only pupils and their parents, or one could introduce weights taking into account not only geography but also the economic relevance of the sectors involved by restrictions. However, these refinements would require additional data.

Figure A1 shows how the two indices compare. As an example, notice that the Lockdown Index is able to track better than the Oxford Index the tightening of restrictions in Italy occurred in the first days of March. In particular, the latter steeply increased following the quarantine decree targeting 11 municipalities in the Northern Italy on February 24 whereas the former captured the substantial extension of the measures to Lombardia and 14 provinces (March 8), first, and to the entire national territory (March 10), later.

Table A1. Variables involved in the construction of the Lockdown Index.

Variable v	**Index**	$\tilde{v}_{i,j} = 0$	$\tilde{v}_{i,j} = 1$	$\tilde{v}_{i,j} = 2$	$\tilde{v}_{i,j} = 3$
Schools	v_1	No measures	Limited closures	Mostly closed	Closing all levels
Economic Activity	v_2	No measures	Limited closures	Mostly closed	Closing all-but essential productions
Stay at home	v_3	No measures	Recommended	Mandatory	

Figure A1. Comparison between the Lockdown Index and the Oxford Index.



Source: Oxford COVID-19 Government Response Tracker, Hale et al. (2020).